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# Chapter Fourteen
# ROADSIDE SAFETY

The ideal roadway would be free of obstructions or other hazardous conditions within the entire highway right-of-way. This is usually not practical because of economic, environmental or drainage factors. Chapter Fourteen presents clear zone distances which should adequately provide a clear recovery space for the majority of drivers who run off the road. The Chapter also provides criteria for the use of roadside barriers, median barriers, breakaway devices and impact attenuators where providing the clear zone is not practical.

## 14.1 DEFINITIONS/NOMENCLATURE

1. Barrier Warrant. A criterion that identifies an area of concern which should be shielded by a traffic barrier, if judged to be practical.

2. Critical Parallel Slope. Slopes which cannot be safely traversed by a run-off-the-road vehicle. Depending on the encroachment conditions, a vehicle on a critical slope may overturn. For most embankment heights, fill slopes steeper than 3:1 are considered critical.

3. Edge of Travel Lane (ETL). The line between the portion of the roadway used for the movement of vehicles and the shoulder. The edge of travel lane is the center line, when considering opposing traffic.

4. Edge of Traveled Way (ETW). The line between the portion of the roadway used for the movement of vehicles and the shoulder regardless of the direction of travel.

5. Impact Angle. For a longitudinal barrier, the angle between a tangent to the face of the barrier and a tangent to the vehicle's path at impact. For a crash cushion, it is the angle between the axis of symmetry of the crash cushion and a tangent to the vehicular path at impact.

6. Impact Attenuator (Crash Cushion). A traffic barrier used to safely shield fixed objects or other obstacles of limited dimension from approximately head-on impacts by errant vehicles.

7. Length of Need. Total length of a longitudinal barrier, measured with respect to the centerline of roadway, needed to shield an area of concern. The length of need is measured to the last point of full-strength rail.

8. Median Barrier. A longitudinal barrier used to prevent an errant vehicle from crossing the median of a divided highway. This prevents collisions between traffic traveling in opposite directions.

9. Non-Recoverable Parallel Slope. Slopes which can be safely traversed but upon which an errant motorist is unlikely to recover. The run-off-the-road vehicle will likely continue down the slope and reach its toe. For most embankment heights, if a fill slope is between 3:1 (inclusive) and 4:1 (exclusive), it is considered a non-recoverable parallel slope.

10. Parallel Slopes. Cut and fill slopes for which the toe runs approximately parallel to the flow of traffic.

11. Recoverable Parallel Slope. Slopes which can be safely traversed and upon which an errant motorist has a reasonable opportunity to stop and return to the roadway. Fill slopes 4:1 and flatter are considered recoverable.

12. Roadside Barrier. A longitudinal barrier used to shield obstacles located within an established clear zone. Roadside barriers include guardrail, half-section concrete median barriers, etc.

13. Roadside Clear Zones. The total roadside border area, starting at the edge of the traveled way, available for safe use by errant vehicles. This area may consist of a shoulder, a recoverable slope, a non-recoverable slope and/or a recovery area. The desired width is dependent upon traffic volumes, speeds and roadside geometry.

14. Roadside Obstacles. A general term to describe roadside features which cannot be safely impacted by a run-off-the-road vehicle. Roadside obstacles include both fixed objects and non-traversable roadside features (e.g., rivers).

15. Shy Distance. Distance from the edge of the traveled way beyond which a roadside object will not be perceived as an immediate hazard by the typical driver to the extent that he will change vehicular placement or speed.

16. Transverse Slopes. Cut and fill slopes for which the toe runs approximately perpendicular to the flow of traffic. Transverse slopes are typically formed by intersections between the mainline and approach, median crossovers or side roads.

17. Traversable Slopes. A slope or cross section in which a vehicle can safely cross. Parallel slopes 3:1 or flatter are considered traversable.

18. Utility Occupancy Area. A strip of right-of-way reserved for the placement of utilities.

## 14.2 ROADSIDE CLEAR ZONES

### 14.2.1 General Application

The clear zone widths presented in this *Manual* must be placed in proper perspective. The distances imply a degree of accuracy that does not exist. They do, however, provide a good frame of reference for making decisions on providing a safe roadside area. Each application of the clear zone distance must be evaluated individually, and the designer must exercise good judgment.

Figure 14.2A presents clear zone distances for design. When using the recommended distances, the designer should consider the following:

1. Context. If a formidable obstacle (see Section 14.3.3) lies just beyond the clear zone, it may be appropriate to remove or shield the obstacle if costs are reasonable. Conversely, the clear zone should not be achieved at all costs. Limited right-of-way or unacceptable construction costs may result in unshielded obstacles within the clear zone or may lead to the installation of a barrier. Unshielded obstacles within the clear zone, including the adjusted $CZ_C$ for horizontal curves, must be approved through the design exception process. See Section 8.8.

2. Boundaries. The designer should not use the clear zone distances as boundaries for introducing roadside obstacles such as bridge piers, non-breakaway sign supports, utility poles or landscaping features. Place these items as far from the traveled way as practical.

3. Roadside Cross Section. The recommended clear zone distance will be based on the type of roadside cross section. Section 14.2.3 presents several schematics for the various possibilities.

4. Measurement. All clear zone distances are measured from the edge of the traveled way. For auxiliary lanes (e.g., climbing lanes, turning lanes, weaving lanes), the clear zone is measured from the edge of the auxiliary lane based on the mainline design speed and mainline design AADT.

5. Utility Occupancy Area. The designer should note that clear zones and the utility occupancy area, as discussed in the *MDT Utility Accommodation Policy*, are independent dimensions. Place utilities outside of the clear zone or the utility occupancy area, whichever is greater.

| Design Speed | Design AADT | Fill Slopes/Foreslopes | | | |
|---|---|---|---|---|---|
| | | 6:1 or Flatter | 5:1 | 4:1 | 3:1 |
| 60 km/h or less | < 750 | 2.0 m | 2.0 m | 3.0 m | See Procedure in Section 14.2.3. |
| | 750-1499 | 3.0 m | 3.5 m | 4.5 m | |
| | 1500-6000 | 3.5 m | 4.5 m | 5.0 m | |
| | > 6000 | 4.5 m | 5.0 m | 5.5 m | |
| 70 km/h | < 750 | 3.0 m | 3.5 m | 4.0 m | |
| | 750-1499 | 4.5 m | 5.0 m | 5.5 m | |
| | 1500-6000 | 5.0 m | 6.0 m | 6.5 m | |
| | > 6000 | 6.0 m | 7.5 m | 8.0 m | |
| 80 km/h | < 750 | 3.5 m | 4.0 m | 4.5 m | |
| | 750-1499 | 5.0 m | 5.5 m | 6.0 m | |
| | 1500-6000 | 5.5 m | 7.0 m | 8.0 m | |
| | > 6000 | 6.5 m | 8.0 m | 8.5 m | |
| 90 km/h | < 750 | 3.5 m | 4.5 m | 5.5 m | |
| | 750-1499 | 5.0 m | 6.0 m | 7.5 m | |
| | 1500-6000 | 6.0 m | 7.5 m | 9.0 m | |
| | > 6000 | 6.5 m | 8.0 m | 10.0 m | |
| 100 km/h | < 750 | 5.0 m | 6.0 m | 7.5 m | |
| | 750-1499 | 6.0 m | 8.0 m | 10.0 m | |
| | 1500-6000 | 8.0 m | 10.0 m | 12.0 m | |
| | > 6000 | 9.0 m | 11.0 m | 13.5 m | |
| 110 km/h | < 750 | 5.5 m | 6.0 m | 8.0 m | |
| | 750-1499 | 7.5 m | 8.5 m | 11.0 m | |
| | 1500-6000 | 8.5 m | 10.5 m | 13.0 m | |
| | > 6000 | 9.0 m | 11.5 m | 14.0 m | |

*Notes:*

1. *All distances are measured from the edge of the traveled way (ETW).*

2. *For clear zones, the “Design AADT” will be the total AADT for both directions of travel. This applies to both divided and undivided facilities.*

3. *See Section 14.2.2 for adjustments on horizontal curves.*

4. *See Section 14.2.4 for clear zones in cut sections.*

**CLEAR ZONE DISTANCES (m)**
**(Fill Slopes/Foreslopes)**
**Figure 14.2A**

6. Roadside Clear Zone. The recommended clear zone distance from Figure 14.2A should be selected based on the highway design speed, geometric features, slope condition and traffic volumes. Generally, select the clear zone distance for the steepest slope encountered when more than one slope falls within the clear zone.

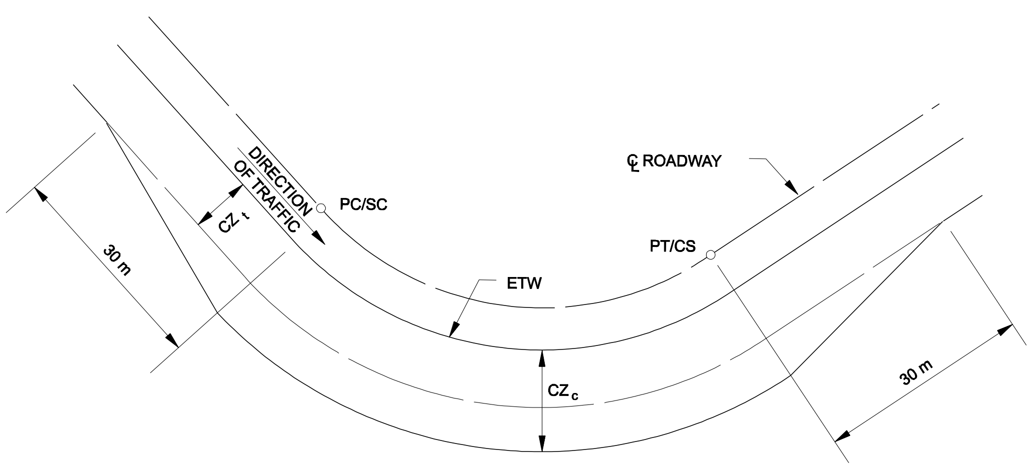
7. Design AADT. For clear zones, the "Design AADT" will be the total AADT of the roadway including both directions of travel. This applies to both divided and undivided facilities.

### 14.2.2 Horizontal Curves

On the outside of horizontal curves, run-off-the-road vehicles may travel a farther distance from the traveled way before regaining control of the vehicle. The designer should modify the clear zone distance obtained from Figure 14.2A for horizontal curvature. The modified value for horizontal curves will be used to determine if a design exception to the clear zone criteria is necessary; see Section 14.2.6.

Figure 14.2B illustrates the application of the clear zone adjustment on a curve. Figure 14.2C provides recommended adjustments for horizontal curves.

On the inside of horizontal curves, use the clear zone distance for a tangent roadway.




$CZ_t$ = clear zone on tangent section
$CZ_c$ = clear zone on horizontal curve
ETW = edge of traveled way

**HORIZONTAL CURVE ADJUSTMENTS**
**Figure 14.2B**

| Radius (m) | Design Speed (km/h) | | | | | |
|---|---|---|---|---|---|---|
| | 60 | 70 | 80 | 90 | 100 | 110 |
| 900 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 |
| 700 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.3 |
| 600 | 1.1 | 1.2 | 1.2 | 1.2 | 1.3 | 1.4 |
| 500 | 1.1 | 1.2 | 1.2 | 1.3 | 1.3 | 1.4 |
| 450 | 1.2 | 1.2 | 1.3 | 1.3 | 1.4 | 1.5 |
| 400 | 1.2 | 1.2 | 1.3 | 1.3 | 1.4 | |
| 350 | 1.2 | 1.2 | 1.3 | 1.4 | 1.5 | |
| 300 | 1.2 | 1.3 | 1.4 | 1.5 | 1.5 | |
| 250 | 1.3 | 1.3 | 1.4 | 1.5 | | |
| 200 | 1.3 | 1.4 | 1.5 | | | |
| 150 | 1.4 | 1.5 | | | | |
| 100 | 1.5 | | | | | |

Notes:

1. Adjustments apply to the outside of a horizontal curve.

2. Curve radii greater than 900 m do not require adjustments.

3. The applicable clear zone distance on a horizontal curve is calculated by:

$$CZ_C = (K_{CZ})(CZ_T)$$

where: $CZ_C$ = clear zone on outside of curve, m

$K_{CZ}$ = curve adjustment factor

$CZ_T$ = clear zone on a tangent section from Figure 14.2A, m

4. For curves intermediate in the table, use a straight-line interpolation.

5. See Figure 14.2B for the application of $CZ_C$ to the roadside around a curve.

6. Round the computed clear zone distance up to the next highest 0.5 m increment.

**CLEAR ZONE ADJUSTMENT FACTORS FOR HORIZONTAL CURVES $(K_{CZ})$**

**Figure 14.2C**

### 14.2.3 Parallel Slopes

Figure 14.2A presents the Department's criteria for clear zones on fill slopes which run parallel to the highway. The following discusses the application of the figure:

1. Recoverable Fill Slopes. For parallel fill slopes 4:1 and flatter (Figure 14.2D(a)), the recommended clear zone distance can be determined directly from Figure 14.2A.

2. Non-Recoverable Fill Slopes. For parallel fill slopes between 3:1 (inclusive) and 4:1 (exclusive) (Figure 14.2D(b)), adjust the clear zone to include a recovery area beyond the toe of the fill slope. It is recommended that sufficient right-of-way be purchased to ensure that the recovery area can be maintained and cleared of obstacles. The following procedure is used to determine the adjusted clear zone:

    a. Ensure that the slope in the recovery area beyond the toe is 4:1 or flatter. Determine the clear zone from Figure 14.2A using the slope rate beyond the toe, the applicable design speed and traffic volume.

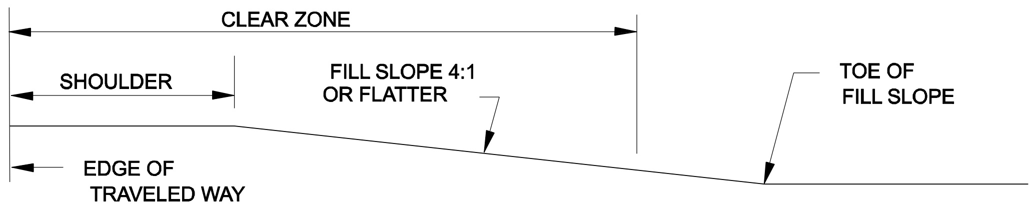
    b. To determine the recovery area distance beyond the toe, subtract the width of the recoverable slope(s) between the ETW and the hinge point from the distance in Step #2a.

    c. If the distance in Step #2b is greater than or equal to 3.0 m, this distance will be the width of the recovery area. If the distance in Step #2b is less than 3.0 m, the minimum recovery area will be 3.0 m beyond the toe.

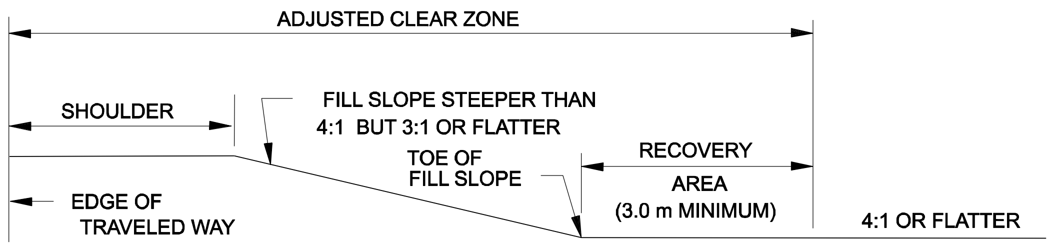
    d. The adjusted clear zone is the distance from the edge of the traveled way to the outside limit of the recovery area; see Figure 14.2D(b).

    e. The designer should check to determine if a recoverable parallel slope(s) can be incorporated from the shoulder to the adjusted clear zone as determined in Step #'s 2b and 2c. The designer must review the benefits of providing a flatter slope versus the cost for additional embankment fill.

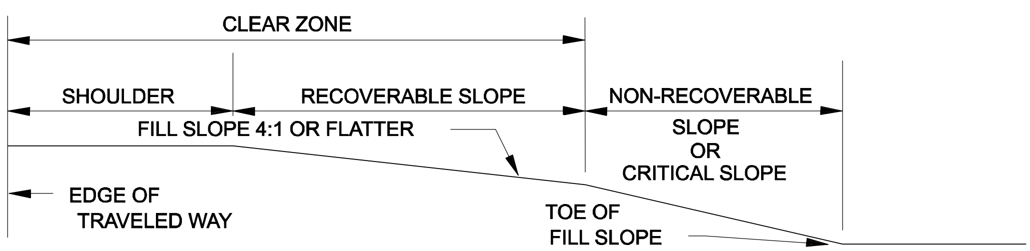
3. Barn-Roof Fill Slope (Recoverable/Recoverable). Barn-roof fill slopes may be designed with two recoverable slope rates; the second slope is steeper than the slope adjacent to the shoulder. This design requires less right-of-way and embankment material than a continuous, flatter slope. However, the use of barn-roof slopes are exceptions to the Department’s slope criteria; see Section 8.8. The clear zone is determined by using the steeper slope, although a "weighted" average of the slopes may be used to justify a narrower clear zone where necessary to provide a practical design.



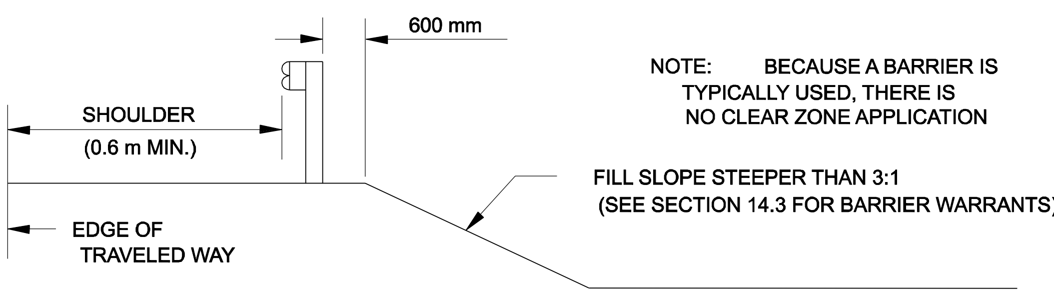

RECOVERABLE PARALLEL SLOPE (a)




NON-RECOVERABLE PARALLEL SLOPE (b)




BARN-ROOF PARALLEL SLOPE (c)




CRITICAL PARALLEL SLOPE (d)

**CLEAR ZONE APPLICATION FOR FILL SLOPES**
**Figure 14.2D**

4. Barn-Roof Fill Slope (Recoverable/Non-Recoverable). Barn-roof fill slopes may be designed with a recoverable slope leading to a non-recoverable slope (Figure 14.2D(c)). The clear zone should be provided entirely on the recoverable slope (i.e., the shoulder and recoverable slope should equal the clear zone distance). If the clear zone based on the recoverable slope extends beyond the slope break between the recoverable and non-recoverable slope, use the procedure in No. 2 above to determine the lateral extent of the clear zone.

5. Barn-Roof Fill Slope (Recoverable/Critical). Barn-roof fill slopes may be designed with a recoverable slope leading to a critical slope (i.e., fill slopes steeper than 3:1). See Figure 14.2D(c). This barn-roof design may only be used if there are no other practical alternatives. The clear zone based on the recoverable slope rate must be provided entirely on the recoverable slope (i.e., the clear zone must equal or be less than the sum of the shoulder width and recoverable slope width). Otherwise, a barrier may be warranted. See Section 14.3.2. Note, a barn-roof slope cannot be used to eliminate guardrail.

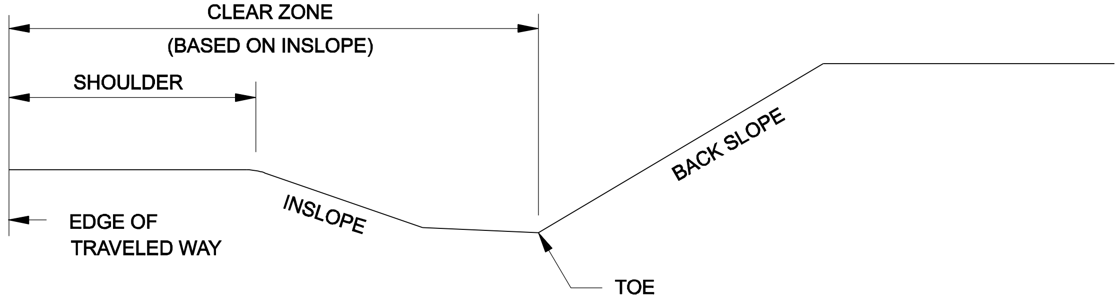
6. Critical Fill Slope. Fill slopes steeper than 3:1 are critical (Figure 14.2D(d)). These fill slopes may require a barrier and, therefore, there is no clear zone application. See Section 14.3.2.

### 14.2.4 Cut Slopes

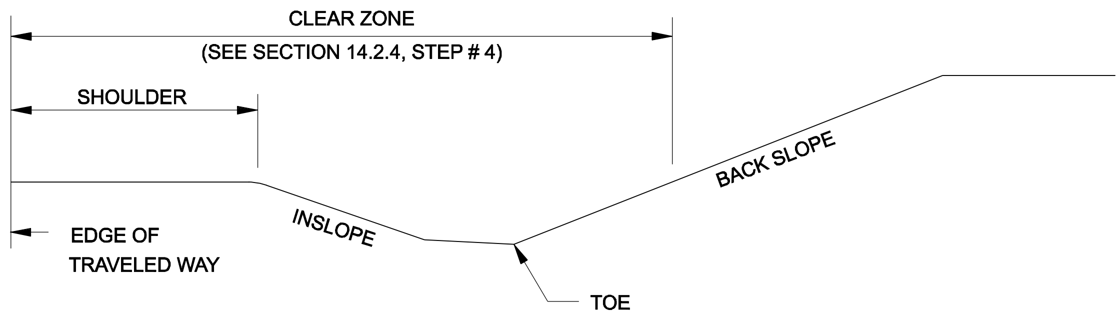
Ditch sections, as illustrated in Figure 14.2E, are typically constructed in roadside cuts without curbs. The applicable clear zone across a ditch section will depend upon the inslope, the back slope, the horizontal location of the toe of the back slope, and various highway factors. Use the following procedure to determine the recommended clear zone distance:

1. Check Inslope. Use Figure 14.2A to determine the clear zone based on the ditch inslope.

2. Check Location of the Toe of Back Slope. Based on the distance from Step #1, determine if the toe of the back slope is within the clear zone. The toe of back slope is defined as the intersection of the ditch bottom and the back slope. If the toe is at or beyond the clear zone, then the designer usually need only consider roadside obstacles within the clear zone on the inslope and within the ditch. If the toe is within the clear zone, the designer should evaluate the practicality of relocating the toe of back slope. If the toe of back slope will remain within the clear zone, Step #4 will apply.




TOE OF BACK SLOPE NOT WITHIN CLEAR ZONE (a)




TOE OF BACK SLOPE WITHIN CLEAR ZONE (b)

**CLEAR ZONE APPLICATION FOR CUT SLOPES**
**Figure 14.2E**

3. Check Ditch Traversability. The designer should evaluate the traversability of the ditch cross section. See Section 14.3.6.1. If the ditch is not traversable, it should be relocated outside the clear zone or reconstructed to an acceptable cross section.

4. Check for Roadside Obstacles on Back Slope (Earth Cuts). If the toe of the back slope is within the clear zone distance from Step #1 above and the ditch is traversable, provide a clear zone on the back slope. This clear zone will be a distance beyond the toe of back slope as follows:

   a. Calculate the percentage of the clear zone available to the toe of the back slope.

   b. Subtract this percentage from 100% and multiply the results by the clear zone for the back slope in Figure 14.2F.

   c. Add the available clear zone to the toe of the back slope to the value determined in Step #4b. Round the total up to the next highest 0.5 m increment. This yields the required clear zone from the edge of traveled way to a point on the back slope.

5. Clear Zones (Rock Cuts). In rock cuts with steep back slopes, no clear zone is required beyond the toe of back slope. The rock cut should be relatively smooth to minimize the hazards of vehicular impact. If the face of the rock is rough or rock debris occurs in the ditch section, a barrier may be warranted.

* * * * * * * * * *

Example 14-1 (Earth Ditch Section)

Given: AADT = 7000
V = 100 km/h
Tangent Roadway
Inslope = 6:1
Ditch Width = 3.0 m
Back Slope = 4:1
Toe of back slope is 6.0 m from edge of traveled way.
See Figure 14.2G.

Problem: Determine the clear zone application across the ditch section.

| Design Speed | Design AADT | Back Slopes | | | |
|---|---|---|---|---|---|
| | | 6:1 or Flatter | 5:1 | 4:1 | 3:1 |
| 60 km/h or less | < 750 | 2.0 | 2.0 | 2.0 | 2.0 |
| | 750-1499 | 3.0 | 3.0 | 3.0 | 3.0 |
| | 1500-6000 | 3.5 | 3.5 | 3.5 | 3.5 |
| | > 6000 | 4.5 | 4.5 | 4.5 | 4.5 |
| 70 km/h | < 750 | 3.0 | 3.0 | 2.5 | 2.5 |
| | 750-1499 | 4.5 | 4.0 | 3.5 | 3.0 |
| | 1500-6000 | 5.0 | 4.5 | 4.5 | 3.5 |
| | > 6000 | 6.0 | 5.5 | 5.5 | 4.5 |
| 80 km/h | < 750 | 3.0 | 3.0 | 3.0 | 2.5 |
| | 750-1499 | 5.0 | 4.5 | 4.0 | 3.0 |
| | 1500-6000 | 5.5 | 5.0 | 4.5 | 4.5 |
| | > 6000 | 6.5 | 6.0 | 5.5 | 5.0 |
| 90 km/h | < 750 | 3.0 | 3.0 | 3.0 | 2.5 |
| | 750-1499 | 5.0 | 5.0 | 4.5 | 3.0 |
| | 1500-6000 | 6.0 | 5.5 | 5.0 | 4.5 |
| | > 6000 | 6.5 | 6.5 | 6.0 | 5.0 |
| 100 km/h | < 750 | 4.5 | 4.5 | 3.5 | 3.0 |
| | 750-1499 | 6.0 | 5.5 | 5.0 | 3.5 |
| | 1500-6000 | 7.5 | 6.5 | 5.5 | 4.5 |
| | > 6000 | 8.0 | 8.0 | 7.5 | 6.0 |
| 110 km/h | < 750 | 4.5 | 4.5 | 4.5 | 3.0 |
| | 750-1499 | 6.0 | 6.0 | 5.5 | 3.5 |
| | 1500-6000 | 8.0 | 7.5 | 6.5 | 5.0 |
| | > 6000 | 8.5 | 8.5 | 8.0 | 6.5 |

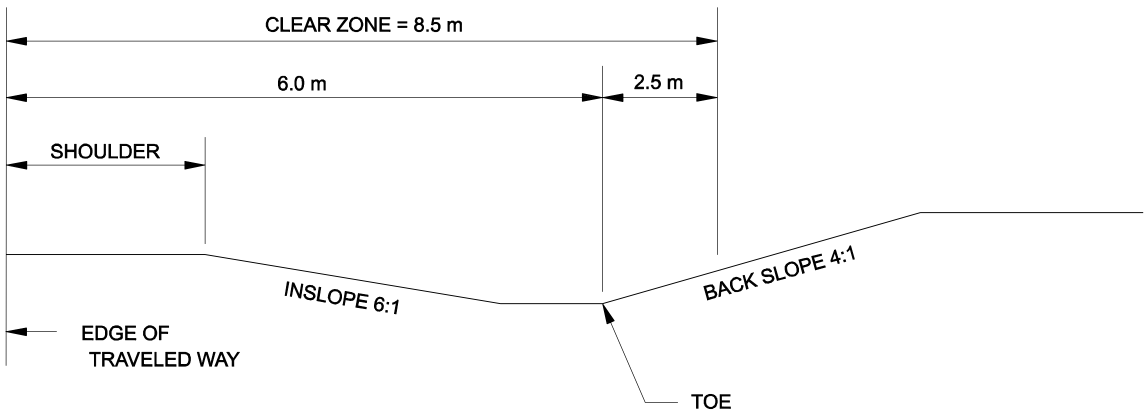
Notes:

1. *All distances are measured from the edge of the traveled way (ETW).*

2. *For clear zones, the "Design AADT" will be the total AADT for both directions of travel. This applies to both divided and undivided facilities.*

3. *See Section 14.2.2 for adjustments on horizontal curves.*

**CLEAR ZONE DISTANCES (m)**
**(Back Slopes in Earth Cuts)**
**Figure 14.2F**




**CLEAR ZONE AT DITCH SECTION**
**(Example 14-1)**
**Figure 14.2G**

Solution: Using the procedure in Section 14.2.4.

1. Check Inslope. Figure 14.2A yields a clear zone of 9.0 m for a 6:1 inslope.

2. Check Location of Toe of Back Slope. The toe of back slope is within the clear zone. Therefore, Step #4 applies.

3. Check Ditch Traversability. As discussed in Section 14.3.6.1, the ditch in this example is a traversable ditch and, therefore, is not a roadside hazard.

4. Check for Roadside Obstacles on Back Slope. Using the procedure in Step #4:

   a. The percentage of the clear zone available to the toe of back slope is 6/9 = 67%.

b. Subtracting this percentage from 100% yields: 100 - 67 = 33%. Figure 14.2F yields a clear zone on a 4:1 back slope of 7.5 m. Multiplying this by 33% yields: (7.5) (0.33) = 2.5 m

c. Adding 2.5 m to 6.0 m yields 8.5 m. Therefore, the total clear zone is 8.5 m from the edge of traveled way or 2.5 m up the 4:1 back slope.

* * * * * * * * * *

### 14.2.5 Curbed Sections

The clear zone width is not reduced due to the presence of curb. However, because substantial development typically occurs in these areas, it is usually impractical to remove or shield all obstacles within the clear zone. Use the following guidelines when curbs are encountered:

5. Horizontal Clearance. On low-speed urban streets (V ≤ 70 km/h), the minimum horizontal clearance to an obstruction is 500 mm from the face of curb. However, if practical, provide a 1.5 m to 3.0 m clearance, especially at intersections and driveway entrances.

6. Sidewalks. Where sidewalks are adjacent to the curb (i.e., there is no border area), locate all appurtenances behind the sidewalk, if practical. In addition, the designer must ensure that sufficient sidewalk width is available between appurtenances and the curb to meet the ADA clearance criteria; see Chapter Eighteen.

### 14.2.6 Design Exceptions

The designer must seek a geometric design exception when the proposed design does not provide the clear zone criteria presented in this Section, including the horizontal curve adjustment in Section 14.2.2; i.e., the adjusted clear zone on a horizontal curve section will be used to determine if a design exception is required. Design exceptions are also required for unshielded obstacles within the clear zone and for shielding obstacles outside of the clear zone. See Section 8.8 for the geometric design exception process.

## 14.3 ROADSIDE BARRIER WARRANTS

### 14.3.1 Range of Treatments

If a roadside obstacle is within the clear zone, the designer should select the treatment which is judged to be the most practical and cost-effective for the site conditions. The range of treatments listed in order of preference include:

1. eliminate the obstacle (flatten embankment, remove rock outcroppings, etc.);
2. relocate the obstacle;
3. where applicable, make the obstacle breakaway (sign posts, luminaire supports);
4. shield the obstacle with a roadside barrier; or
5. do nothing.

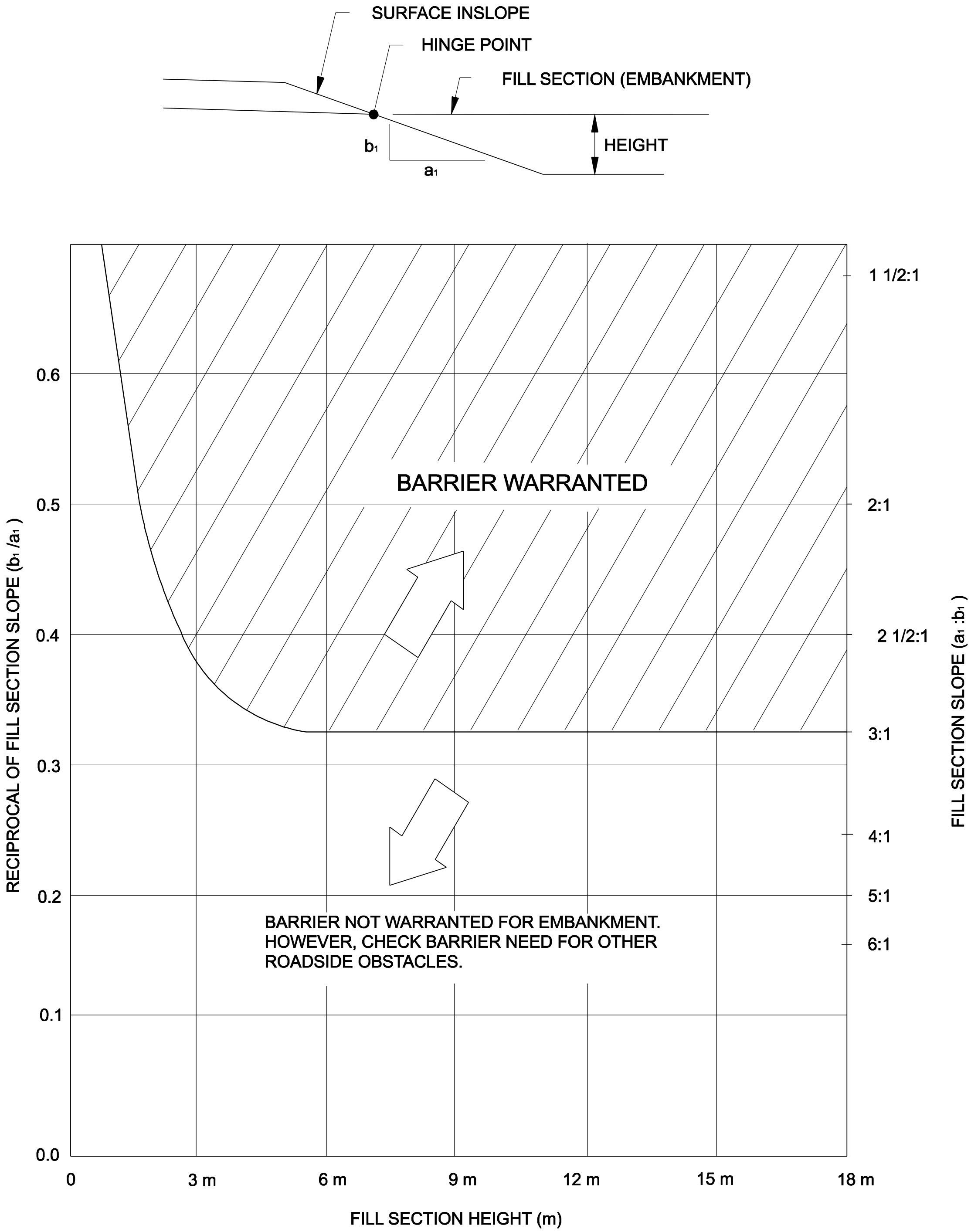
The selected treatment will be based upon the traffic volumes, roadway geometry, proximity of the obstacle to traveled way, nature of the hazard, costs for remedial action and accident experience. Where used, the designer should ensure that any roadside barrier installations are considered early in the project design. The design of an embankment slope flatter than those required by the MDT design criteria should be documented in the Scope of Work or Plan-in-Hand Report. The option to “do nothing” will require a design exception.

### 14.3.2 Embankments

The severity of the roadside embankment depends upon the rate of fill slope and the height of fill. For all highways, use Figure 14.3A to determine if a barrier is warranted. For low embankment heights, the criteria allow fill slopes steeper than 3:1 to remain unshielded. A barrier is not required for areas outside of the shaded region, unless there are roadside obstacles within the clear zone as determined from Section 14.2.

### 14.3.3 14.3.3 Roadside Obstacles

Section 14.2 presents the recommended clear zone distances for various highway conditions. These distances should be free of any fixed or non-traversable obstacles. In general, barrier warrants are based on the relative severity between impacting the barrier and impacting the obstacle. A few examples of roadside obstacles include:




NOTE: POINTS WHICH FALL ON THE SOLID LINE DO NOT WARRANT A BARRIER.

**BARRIER WARRANTS FOR EMBANKMENTS**

**Figure 14.3A**

1. non-breakaway sign supports, non-breakaway luminaire supports, traffic signal poles and railroad signal poles;

2. concrete footings, etc., extending more than 100 mm above the ground;

3. bridge piers and abutments at underpasses, bridge parapet ends and pedestrian rail ends (see Figure 14.3B);

4. retaining walls and culvert headwalls;

5. trees with diameter greater than 100 mm (at maturity);

6. rough rock cuts;

7. large boulders;

8. critical parallel slopes;

9. streams or permanent bodies of water (where the depth of water ≥ 600 mm);

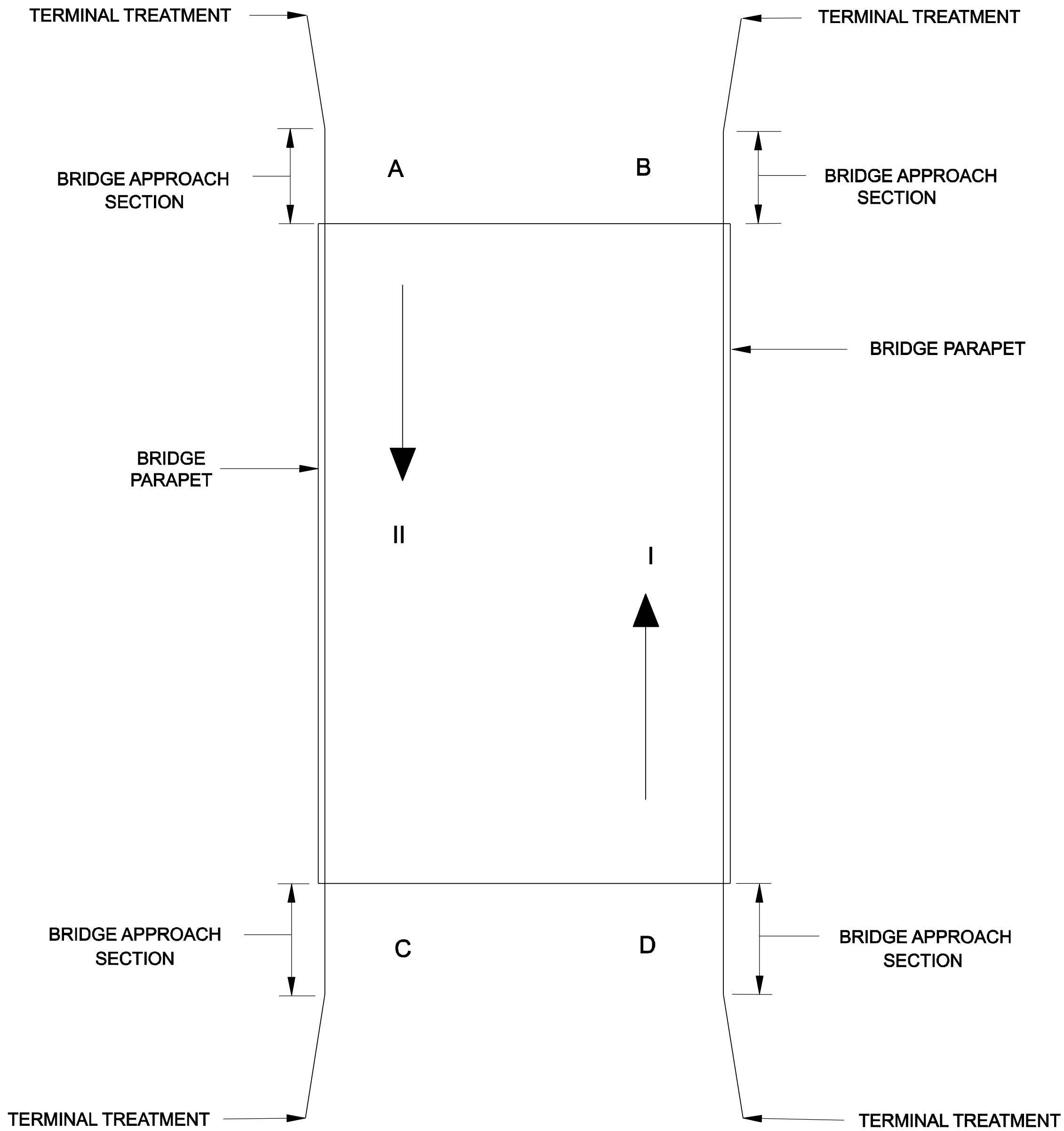
10. non-traversable ditches;

11. utility poles or towers; and

12. culvert ends (> 900 mm).

Once the designer has concluded that an obstacle is located within the clear zone, the first attempt should be to remove or relocate the obstacle or to make the object breakaway. If these are not practical, a barrier should be installed only if engineering judgment indicates it is a reasonable solution. For example, it would probably not be practical to install a barrier to shield an isolated point obstacle, such as a tree, located near the edge of the clear zone.

Shielding obstacles located just outside the clear zone may be appropriate particularly for features installed by the Department or sites that have a crash history. For example, shielding a bridge end location just outside the clear zone may be justified, due to the potential severity of the crash and running speeds higher than the design speeds. These situations should be reviewed during the development of the project.




| TRAFFIC DIRECTION | BRIDGE APPROACH SECTION REQUIRED AT * |
|---|---|
| I and II | A B C D |
| II Only | A B |
| I Only | C D |

* ONLY IF WITHIN CLEAR ZONE OF APPROACHING TRAFFIC

**BARRIER WARRANTS AT BRIDGES**

**Figure 14.3B**

## 14.3.4 Transverse Slopes

Where the highway mainline intersects an approach, side road or median crossing, a slope transverse to the mainline will be present. See Figure 14.3C. In general, transverse slopes should be as flat as practical. The following will apply:

1. High-Speed Facilities. For high-speed facilities (V > 70 km/h), provide a transverse slope no steeper than 6:1. Transverse slopes of 10:1 are desirable where practical.

2. Low-Speed/Urban Facilities. For low-speed facilities (V ≤ 70 km/h) and for non-freeways in urban areas, transverse slopes should desirably be 6:1 or flatter. Where necessary, steeper transverse slopes may be used to provide practical designs (e.g., urban facilities with closely spaced driveways).

Use these criteria for slopes within the clear zone. Slopes may be transitioned to a steeper slope beyond the clear zone. Where these criteria cannot be practically met in rural areas, consider providing a roadside barrier. The decision to use a barrier will be made on a case-by-case basis considering costs, traffic volumes, severity of the proposed transverse slope and other relevant factors.

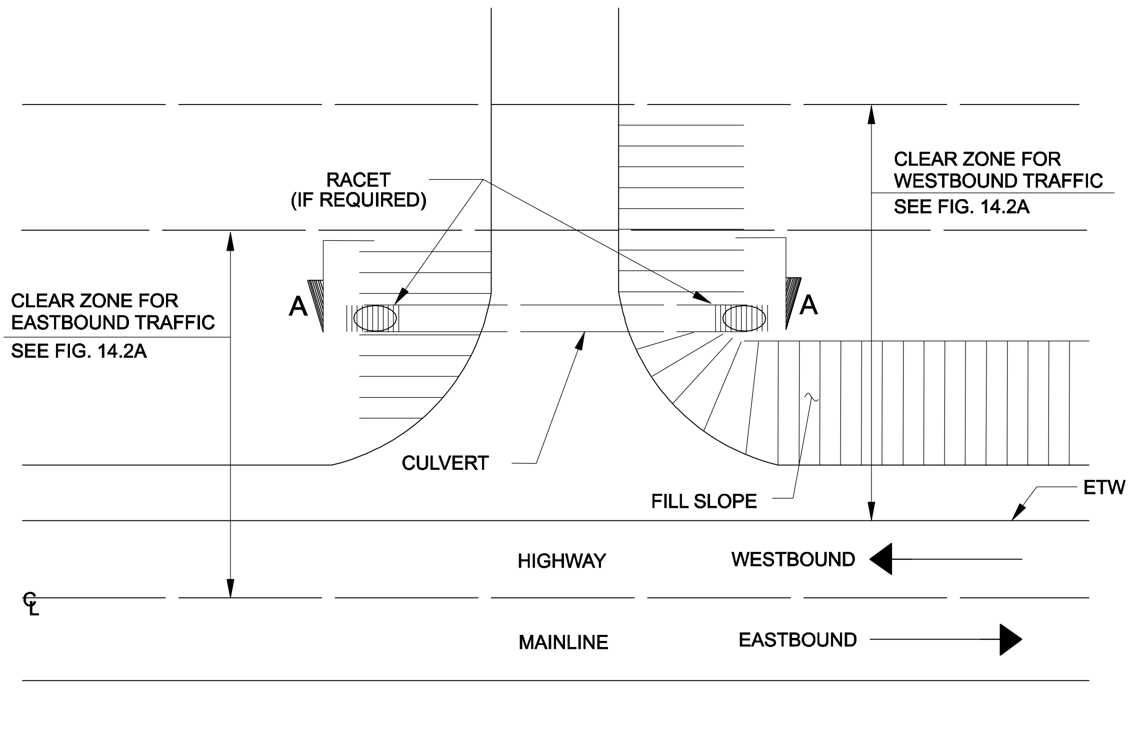
## 14.3.5 Rock Cuts

As indicated in Section 14.3.3, rough rock cuts located within the clear zone may be considered a roadside obstacle. The following will apply to their treatment:

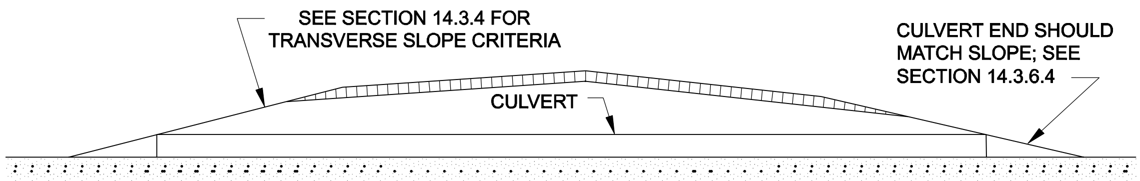
1. <u>Obstacle Identification</u>. There is no precise method to determine whether or not a rock cut is sufficiently "ragged" to be considered a roadside obstacle. This will be a judgment decision based on a case-by-case evaluation.

2. <u>Debris</u>. A roadside obstacle may be identified based on known or potential occurrences of rock debris encroaching onto the roadway. If rock debris is expected within the clear zone, a barrier for capturing the debris may be required. Contact the Geotechnical Section to determine the length of need and type of barrier required.

3. <u>Barrier Warrant</u>. If the rock cut is within the clear zone, a barrier may be warranted.




NOTE: ON A 1-WAY FACILITY, THE RACET ON THE DEPARTURE SIDE OF THE APPROACH IS NOT REQUIRED.




SECTION A-A

**TRANSVERSE SLOPES**
**ON A 2-LANE, 2-WAY ROADWAYS**
**Figure 14.3C**

## 14.3.6 Roadside Drainage Features

Effective drainage is one of the most critical elements in the design of a roadway or street. Drainage features should be designed and constructed considering their consequences on run-off-the-road vehicles. Ditches, curbs, culverts and drop inlets are common drainage system elements that should be designed, constructed and maintained considering both hydraulic efficiency and roadside safety.

In general, the following options, listed in order of preference, are applicable to all drainage features:

1. Construct or relocate outside the clear zone.

2. Design or modify drainage structures, with diameters greater than 900 mm, so that they are traversable or present a minimal hazard to an errant vehicle.

3. If a drainage feature, with diameters greater than 900 mm, cannot effectively be redesigned or relocated, consider shielding by a traffic barrier if the feature is in a vulnerable location and if a barrier installation is judged to be cost effective.

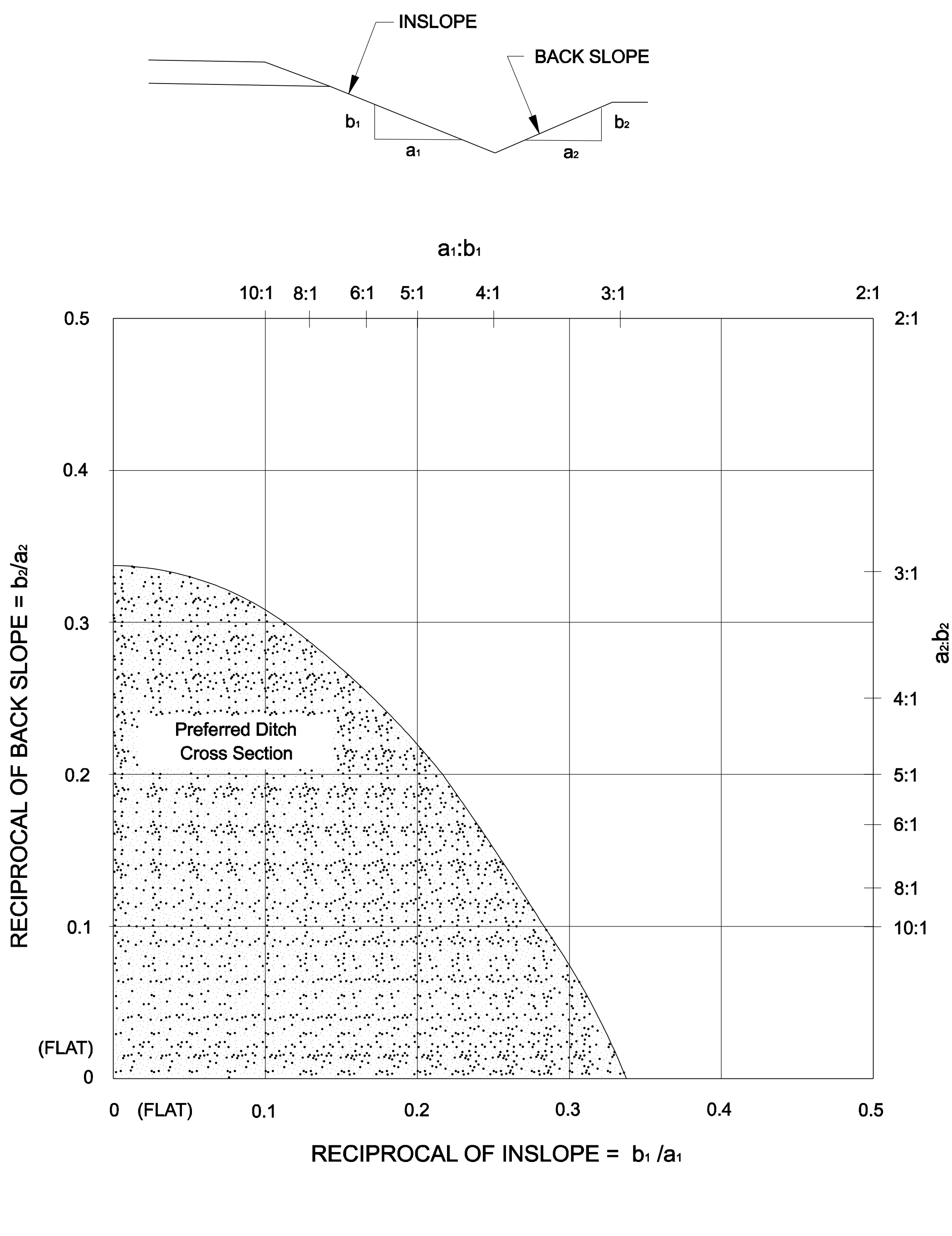
### 14.3.6.1 Roadside Ditches

Figures 14.3D and 14.3E present inslope and back slope combinations for basic ditch configurations. Cross sections which fall in the shaded region of each of the figures are considered traversable. Ditch sections which fall outside the shaded region are considered non-traversable and should be redesigned to an acceptable cross section; otherwise, consider providing a roadside barrier.

Chapters Eleven and Twelve present MDT criteria for the configuration of roadside ditches based on functional classification and design speed. In general, these ditch sections meet the traversability criteria in Figures 14.3D and 14.3E.

### 14.3.6.2 Curbs

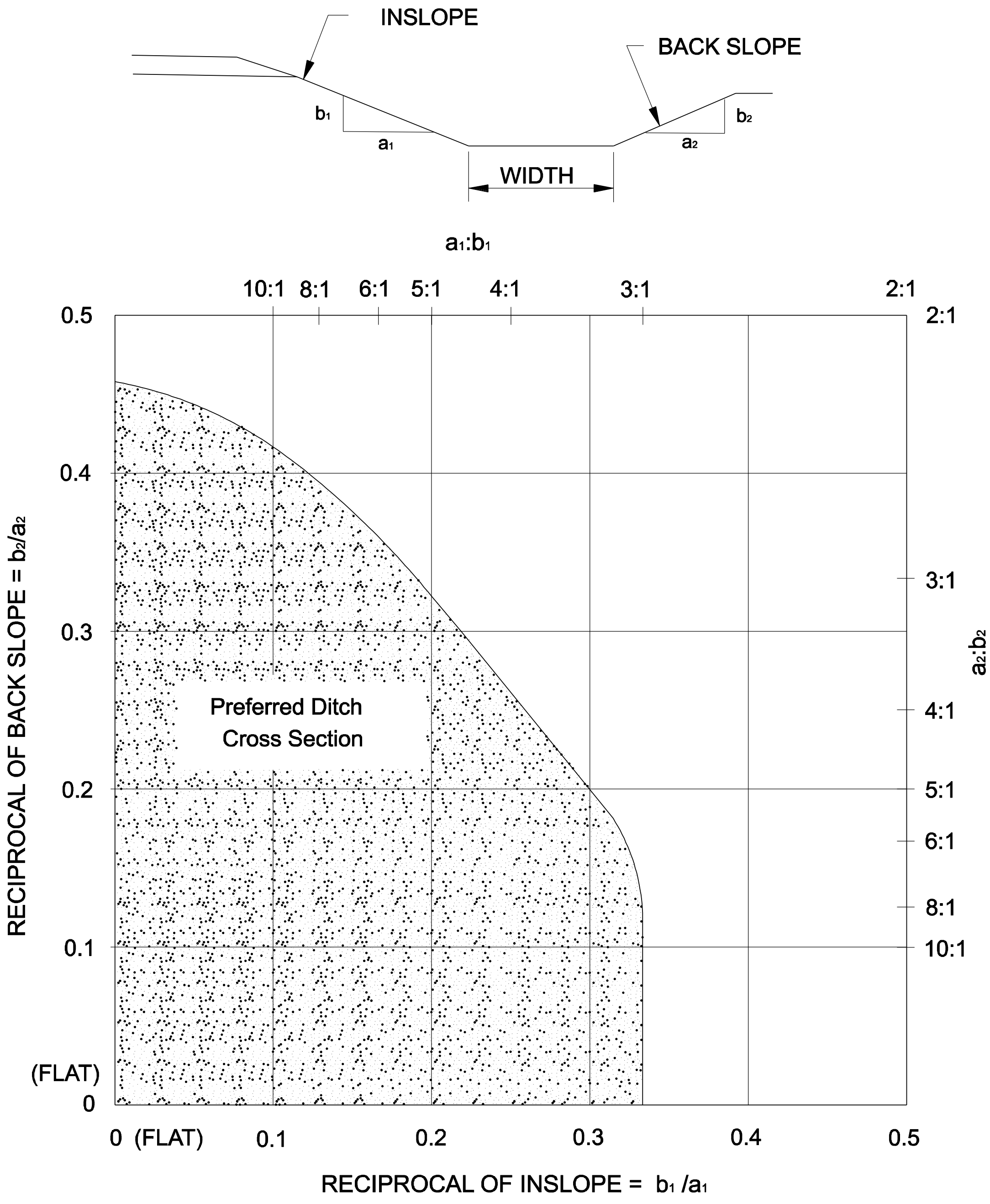
Curbs are typically used for drainage control. In general, curbs should not be used on new construction projects in rural areas. Section 14.4.3 discusses the relative placement of curbs and guardrail. The *MDT Detailed Drawings* provide information on the different types of curbs used by the Department and the criteria for their placement.




*Note: This chart is applicable to all V-ditches, rounded ditches with a bottom width less than 2.4 m, and trapezoidal ditches with bottom widths less than 1.2 m.*

**PREFERRED CROSS SECTIONS FOR DITCHES**
**(With Abrupt Slope Changes)**

**Figure 14.3D**




*Note: This chart is applicable to all rounded ditches with a bottom width of 2.4 m or more and to trapezoidal ditches with bottom widths equal to or greater than 1.2 m.*

**PREFERRED CROSS SECTIONS FOR DITCHES**
**(With Gradual Slope Changes)**

**Figure 14.3E**

#### 14.3.6.3 Cross Drainage Structures

Cross drainage structures should be checked to determine if their inlets/outlets are within the clear zone. If an inlet/outlet is within the clear zone on a recoverable slope, the preferred treatment is to extend the structure so the obstacle is located beyond the clear zone. Extending the pipe on a recoverable slope may result in warping the side slopes to match the opening. The longitudinal transition on both the approach and departure slope should be a minimum of 20 m per unit incremental change in the slope ratio. For example, if the slope ratio changes from 6:1 to 7:1, the transition = 20 m; from 6:1 to 8:1, the transition length = 40 m.

Typically, it is not practical to extend a cross drainage structure to the clear zone when it is located on a non-recoverable slope. A recoverable barn-roof slope can be constructed having a slope that provides adequate clear zone width on top of the pipe. The longitudinal transition criteria should be used to determine the extent of the barn-roof slope. For example, if the existing slope is 3:1 and the barn-roof slope is 6:1, the barn-roof slope should extend 60 m in the direction of approaching traffic. The same criteria would be applied ahead on line if the structure was located within the clear zone of the opposing traffic.

Where extending the culvert is impractical due to site conditions, other treatments (e.g., shielding with a roadside barrier, flattening the slope to provide a recoverable slope, use of a modified end section or requesting an exception to leave the obstacle) should be evaluated at the plan reviews.

For major drainage structures which are costly to extend (e.g., 1.5 m high box culverts), shielding with a roadside barrier may often be the most practical alternative.

#### 14.3.6.4 Parallel Drainage Structures

Parallel drainage culverts are those which are oriented approximately parallel to the main flow of traffic. They are typically used under driveways, field entrances, access ramps, intersecting side roads and median crossovers. As with cross drainage structures, the designer's primary objective should be to keep the parallel drainage structure outside the mainline clear zone, to design generally traversable slopes and to match the culvert opening with adjacent slopes. Section 14.3.4 provides the Department's criteria for transverse slope rates.

Parallel drainage structures within the clear zone should match the selected side slope and be safely treated if practical. Although many of these structures are small and present a minimal target, the addition of pipes and bars perpendicular to the mainline traffic can reduce wheel snagging in the culvert openings. The *MDT Detailed Drawings* provide additional details in the design of the road approach culvert end treatment (RACET). Single pipes with diameters of 375 mm or greater and which are within the clear zone will require a RACET. For multiple-pipe installations, the use of grates for the smaller pipes should be considered.

Parallel drainage structures may be closely spaced in urban areas because of frequent driveways and intersecting roads. In such locations, it may be desirable to convert the open ditch into a closed drainage design and backfill the areas between adjacent driveways. This treatment will eliminate the ditch section and the transverse embankments with pipe inlets and outlets.

# 14.4 ROADSIDE BARRIERS

## 14.4.1 Barrier Types

The following sections briefly describe the roadside barrier types which are approved for use by MDT. The designer should reference the *MDT Detailed Drawings* for detailed design information on each barrier type.

### 14.4.1.1 "W" Beam Guardrail

The "W" beam system with heavy posts is a semi-rigid system. This system has a deflection distance of 1.2 m. In general, this guardrail system is the preferred system for freeways and on high-volume, non-freeway facilities. A major objective of the heavy post system is to prevent a vehicle from "snagging" on the posts. This is achieved by using blockouts to offset the posts from the longitudinal beam and by establishing 1.905 m as the maximum allowable post spacing.

The Department has approved the use of three guardrail "W" beam systems based on post types (wood, steel and concrete). Post selection for a project is at the Contractor's option. However, the Contractor must use the same post type throughout the project.

### 14.4.1.2 Cable Guardrail

Three-cable guardrail is a flexible system with a large dynamic deflection (3.7 m with 4.88 m post spacing). Most of the resistance to impact is supplied by the tensile forces developed in the cable strands. Upon impact, the cables break away from the posts, and the vehicle is able to knock down these posts as it is redirected by the cables. The detached posts do not contribute to controlling the lateral deflection. However, the posts which remain in place do provide a substantial part of the lateral resistance to the impacting vehicle and are therefore critical to proper performance.

Cable guardrail is the safest of the available systems because of its large dynamic deflection. Therefore, it can only be used where a deflection distance of 3.7 m is available behind the guardrail for considerable lengths along the roadside. Its use should be tempered by the following considerations:

1. <u>Snow</u>. Cable guardrail is generally only used where there is a problem with snow drifting.

2. <u>Transitions</u>. Do not use cable guardrail to transition into a bridge rail.

3. <u>Slopes</u>. Do not use cable guardrail on fill slopes steeper than 2:1, unless the distance between the back of the posts and the break in the fill slope is at least

2.4 m. For fill slopes which are 2:1 or flatter, provide a minimum 0.6 m shelf between the back of posts and the break in the fill slope.

4. Minimum Radius. Do not use cable guardrail on the inside of any horizontal curves. If cable guardrail is used on the outside of sharp radius curves, the post spacing may need to be reduced. See Figure 14.4A and the *MDT Detailed Drawings* for the applicable criteria.

5. Maintenance. In general, cable guardrail requires more maintenance after impact than the "W" beam guardrail. Therefore, the higher the probability of impact, the stronger the preference for the "W" beam system.

| Centerline Radius | Maximum Post Spacing |
|---|---|
| $\geq$ 220 m | 4.88 m |
| $\geq$ 135 m & $<$ 220 m | 3.66 m |
| $<$ 135 m | Do not use cable guardrail |

**CABLE GUARDRAIL POST SPACING**
**(On Outside of Horizontal Curves)**
**Figure 14.4A**

### 14.4.1.3 Box Beam Guardrail

Box beam guardrail (weak post) is a semi-rigid system with a dynamic deflection of 1.5 m. Resistance in this system is achieved through the combined flexure and tensile stiffness of the rail. Post near the impact are designed to break or tear away, thereby distributing the impact force to adjacent posts.

Box beam guardrail is generally used in snow drift areas where cable guardrail is not acceptable (e.g., on the inside of curves, where the 3.7 m deflection distance required for cable guardrail is not available). As with cable guardrail, do not use box beam guardrail to transition to a bridge rail.

#### 14.4.1.4 Concrete Median Barrier (CMB)

The CMB should be considered on the roadside to shield rigid objects where no deflection distance is available (i.e., the acceptable deflection distance is 0.0 m). The CMB is typically used in front of rough rock cuts. If a rigid object is not continuous (e.g., bridge piers), the designer may use a half-section CMB. To provide the necessary lateral support, backfill should be provided behind the half-section CMB, or the CMB should be tied to a concrete surface with reinforcing steel. If this is not practical, use the full-section CMB.

#### 14.4.1.5 Portable Barriers for Construction Sites

Chapter Fifteen provides guidance on portable barriers in construction sites.

### 14.4.2 Barrier Selection

#### 14.4.2.1 Performance Criteria

The barrier performance-level requirements must be considered when selecting an appropriate roadside barrier. At the national level, FHWA and AASHTO are continuously examining the performance criteria to evaluate the acceptability of roadside safety appurtenances and testing these appurtenances to determine if they meet these performance criteria. Currently, *NCHRP 350 Recommended Procedures for the Safety Performance Evaluation of Highway Features* has been adopted for application. MDT is responsible for remaining abreast of the state of the technology and revising its roadside safety hardware practices to comply with the national performance criteria.

Most barriers have been developed and tested for passenger cars and offer marginal protection when struck by heavier vehicles at high speeds and other than flat angles of impact. Therefore, if passenger vehicles are the primary concern, the "W" beam or cable guardrail systems will normally be selected. Locations with poor geometrics, high traffic volumes and speeds, high-crash experience, and/or a significant volume of heavy trucks and buses may require a higher performance level barrier. This is especially important if barrier penetration by a vehicle is likely to have serious consequences.

#### 14.4.2.2 Dynamic Deflection

Also consider the dynamic deflection in barrier selection. Section 14.4.1 provides the deflection distances for the various systems. If the deflection distance is not available, stiffen the railing system or use a CMB.

#### 14.4.2.3 Maintenance

Another consideration in selecting the barrier type depends on maintenance of the system. Although the "W" beam can often sustain second hits, it must be repaired with some frequency. In areas of restricted geometry, high speeds, high traffic volumes and/or where railing repair creates hazardous conditions for both the repair crew and for motorists using the roadway, consider using the rigid CMB. The CMB also allows better control of roadside vegetation, and it provides a more convenient means to transition into bridge piers.

Figure 14.4B summarizes the advantages and disadvantages of the roadside barriers used by the Department and summarizes their typical usage.

### 14.4.3 Roadside Barrier Layout

#### 14.4.3.1 Length of Need (General)

A roadside barrier must be extended a sufficient distance upstream from the obstacle (advancement length) to safely protect a run-off-the-road vehicle. Otherwise, the vehicle could travel behind the barrier and impact the obstacle. The designer should recognize that vehicles depart the road at relatively flat angles. Based on a number of field studies, the average angle of departure is estimated to be 10º. The 80th percentile is estimated to be 15º. These flat angles of departure result in the need to extend the barrier a significant distance in front of the obstacle.

The following equation is used to determine the total barrier length for a given roadside condition:

$$L_{TOTAL} = L_{ADJACENT} + L_{OBSTACLE} + L_{OPPOSING} \quad \text{(Equation 14.4-1)}$$

Where:

| | | |
|---|---|---|
| $L_{ADJACENT}$ | = | The length needed in advance of the obstacle required to protect traffic in adjacent lanes. |
| $L_{OBSTACLE}$ | = | The length of the obstacle itself. |
| $L_{OPPOSING}$ | = | The length in advance of the obstacle needed to protect traffic in opposing lanes. |

| SYSTEM | ADVANTAGES | DISADVANTAGES | TYPICAL USAGE |
|---|---|---|---|
| "W"Beam Guardrail | 1. Low initial cost.<br>2. High level of familiarity by maintenance personnel.<br>3. Can safely accommodate wide range of impact conditions for passenger cars.<br>4. Relatively easy installation.<br>5. Remains functional after moderate collisions. | 1. Cannot accommodate impacts by large vehicles at other than flat angles of impact.<br>2. At high-impact locations, will require frequent maintenance.<br>3. Susceptible to vehicular underride and override.<br>4. Susceptible to vehicular snagging (without rub rail). | 1. Non-freeways.<br>2. Freeways. |
| Cable Guardrail | 1. Lowest initial cost.<br>2. Improved underride/override protection.<br>3. Can safely accommodate wide range of impact conditions for passenger cars.<br>4. Relatively easy installation.<br>5. Most forgiving of all systems. | 1. Cannot sustain a second impact.<br>2. Cannot accommodate impacts by large vehicles.<br>3. Cannot be used with curbing.<br>4. Requires significant maintenance after an impact.<br>5. Cannot be placed on inside of any horizontal curve or on outside of horizontal curves with radii less than 135 m<br>6. Cannot be used to transition to bridge rail. | 1. Low-volume non-freeways.<br>2. Areas where there are problems with snow drifting. |
| Concrete Median Barrier | 1. Can accommodate most vehicular impacts without penetration<br>2. Little or no deflection distance required behind barrier.<br>3. Little or no damage sustained for most vehicular impacts; therefore, least need for maintenance.<br>4. No vehicular underride/override potential or snagging potential. | 1. Highest initial cost.<br>2. For given impact conditions, highest occupant decelerations; therefore, least forgiving of barrier systems.<br>3. Reduced performance where offset between traveled way and barrier exceeds 4.5 m. | 1. In front of rough rock cuts.<br>2. Where high traffic volumes are present.<br>3. Where high volumes of large vehicles are present.<br>4. Where snagging is a concern. |
| Box Beam Guardrail | 1. Can be installed on the inside or outside of any curve.<br>2. Less deflection distance than cable guardrail. | 1. High initial cost.<br>2. Cannot sustain a second impact.<br>3. Cannot accommodate impacts by large vehicles.<br>4. Requires significant maintenance after impact.<br>5. Cannot be used to transition to bridge rail. | 1. Areas where there are problems with snow drifting and cable guardrail cannot be used. |

**ROADSIDE BARRIER SELECTION**

**Figure 14.4B**

The designer should note that only a portion of the terminal sections are included in the overall barrier length of need. See the *MDT Detailed Drawings* to determine the portion of the terminal section which may be included in the total length of need for the barrier.

Figure 14.4C illustrates the variables that must be considered in designing a roadside barrier to effectively shield an obstacle. Figure 14.4C also illustrates the use of a flared and non-flared design. A barrier may be flared to:

1. locate the barrier terminal farther from the traveled way,

2. minimize a driver's reaction to an obstacle near the roadway by gradually introducing a parallel barrier installation,

3. transition a roadside barrier closer to the roadway because of an obstacle, or

4. to reduce the total length of barrier need.

Also give consideration to the following disadvantages of flaring guardrail:

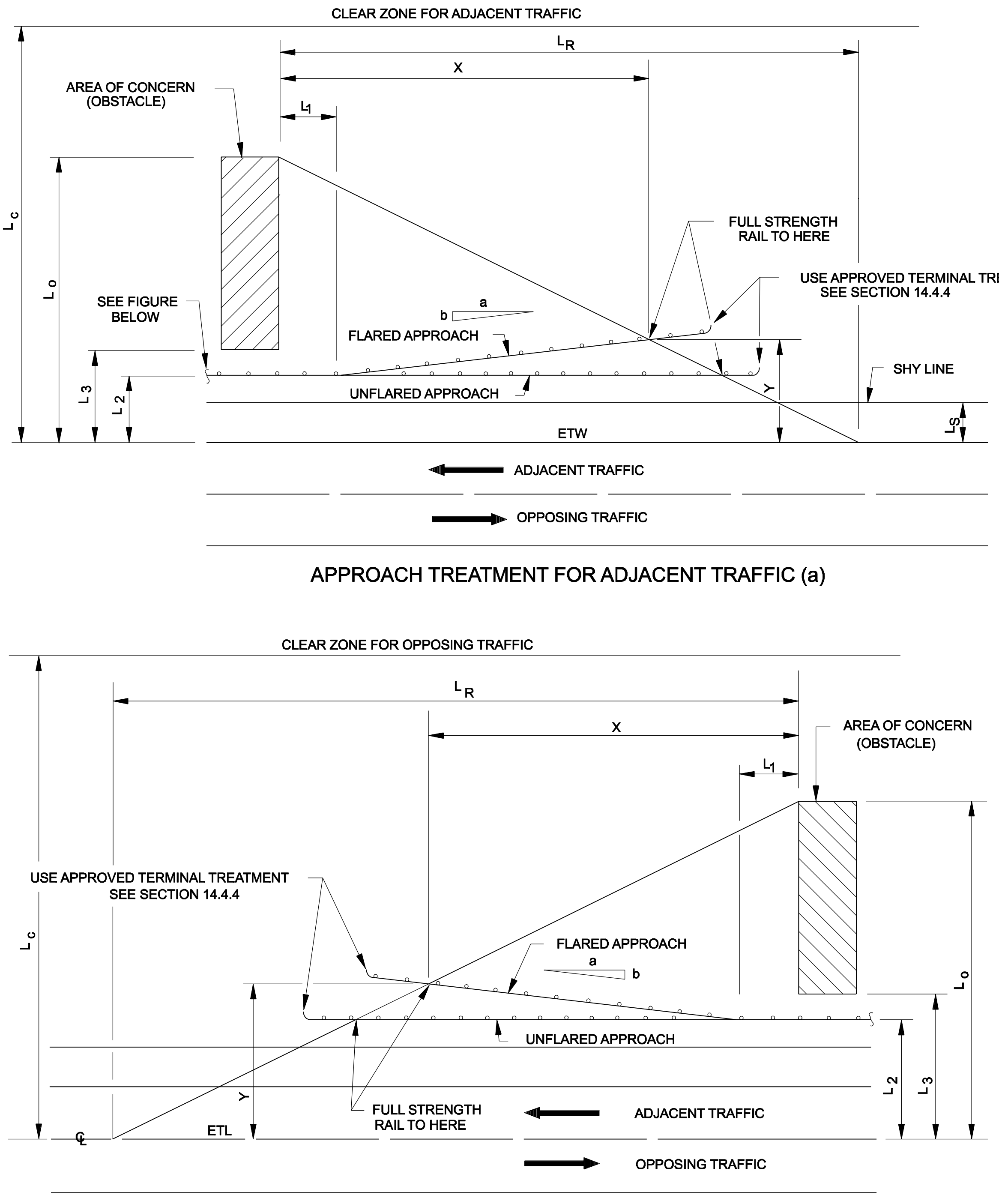
1. Flared rail results in increased impact angles with the potential for greater severity of impact.

2. Flared rail increases the likelihood the vehicle will be redirected into the opposing lane of traffic or across the roadway.

3. Grading required to provide 10:1 or flatter slopes in front of the flared section of guardrail may interfere with roadside drainage and/or may require additional right-of-way.

The preferred installation of advancement guardrail is unflared (placed parallel to the roadway). Flaring the guardrail should only be used after thorough consideration of its advantages and disadvantages. Note that Optional Terminal Sections do not function as effectively when they are flared.

Where fill slopes change within the advancement length of the rail, calculate the advancement lengths using the clear zone for each traversable slope shown on the cross sections adjacent to the obstacle. Compare the results and use the location that produces the shortest length of rail. Generally, do not interpolate intermediate locations of slope changes between cross sections.




APPROACH TREATMENT FOR ADJACENT TRAFFIC (a)



APPROACH TREATMENT FOR OPPOSING TRAFFIC (b)

**BARRIER LENGTH OF NEED**

**Figure 14.4C**

### 14.4.3.2 Length of Need (Embankment/Obstacle That Extends to Edge of the Clear Zone)

Once the appropriate variables have been selected, the required length of need in advance of the obstacle can be calculated from Equations 14.4-2 through 14.4-5. These equations are used when the obstacle is an embankment or a fixed object which extends to or beyond the clear zone:

Flared Design

$$X = \frac{L_O + \frac{b}{a}(L_1) - L2}{\frac{b}{a} + \frac{L_O}{L_R}} \qquad \text{(Equation 14.4-2)}$$

$$Y = L_O - \frac{L_O}{L_R}(X) \qquad \text{(Equation 14.4-3)}$$

Unflared Design

$$X = \frac{L_R(L_O - L_2)}{L_O} \qquad \text{(Equation 14.4-4)}$$

$$Y = L_2 \qquad \text{(Equation 14.4-5)}$$

Where:

$X,Y$ = coordinates of beginning of barrier need.

$a/b$ = barrier flare (e.g., 15:1) (see Figure 14.4D for acceptable rates).

$L_C$ = recommended clear zone.

$L_O$ = distance from edge of traveled way to back of obstacle (i.e., the lateral extent of the obstacle). For a fixed object, the lateral extent of the obstacle ($L_O$) is the distance from the edge of the traveled way to the far side of the obstacle. If the obstacle is an embankment or a fixed object that extends beyond the clear zone, $L_O$ is measured to the outside edge of the clear zone ($L_C$); i.e., $L_O$ = $L_C$.

| Design Speed (km/h) | Runout Length $L_R$ (m) Design Year Traffic Volume (AADT) | | | | Shy Line Offset $L_S$ (m) | Flare Rates (a/b) | | |
|---|---|---|---|---|---|---|---|---|
| | >10 000 | >5000 ≤10 000 | >1000 ≤5000 | ≤1000 | | Inside of Shy Line | Outside of Shy Line: Guardrail | Outside of Shy Line: CMB |
| 110 | 110 | 95 | 80 | 70 | 2.8 | 30:1 | 15:1 | 20:1 |
| 100 | 80 | 65 | 60 | 55 | 2.4 | 26:1 | 14:1 | 18:1 |
| 90 | 75 | 60 | 55 | 50 | 2.2 | 24:1 | 12:1 | 16:1 |
| 80 | 65 | 55 | 50 | 40 | 2.0 | 21:1 | 11:1 | 14:1 |
| 70 | 60 | 50 | 40 | 35 | 1.7 | 18:1 | 10:1 | 12:1 |
| 60 | 50 | 40 | 35 | 30 | 1.4 | 16:1 | 8:1 | 10:1 |
| 50 | 35 | 30 | 25 | 25 | 1.1 | 13:1 | 7:1 | 8:1 |

**DESIGN ELEMENTS FOR BARRIER LENGTH OF NEED**

**Figure 14.4D**

$L_S$ = shy line offset or distance at which barrier is no longer perceived as an obstacle by a driver (see Figure 14.4D).

$L_R$ = runout length (see Figure 14.4D).

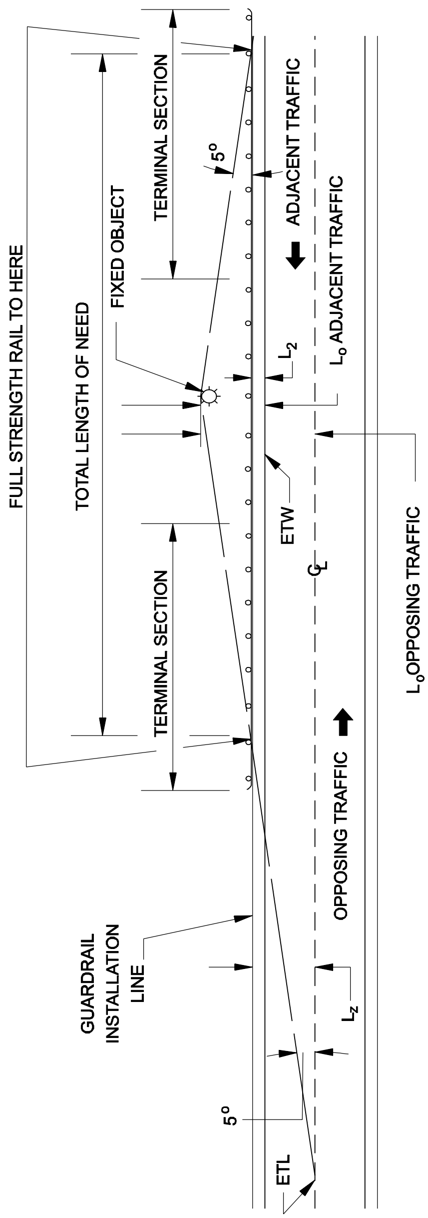
$L_1$ = distance from obstacle to where barrier flare begins. For bridge approaches, this will typically be the bridge transition section. Otherwise, this distance is determined based on engineering judgment.

$L_2$ = distance from edge of traveled way to face of barrier.

$L_3$ = distance from edge of traveled way to front of obstacle. ($L_3$ - $L_2$) must equal or exceed deflection distance.

### 14.4.3.3 Length of Need (Obstacle Within Clear Zone)

Use Equations 14.4-6 through 14.4-9 when the obstacle requiring shielding lies entirely within the clear zone (see Figure 14.4E).




**BARRIER LENGTH OF NEED**
**(Fixed Object Within Clear Zone)**

**Figure 14.4E**

Flared Design

$$X = \frac{(L_O - L_2) + (b/a)L_1}{(b/a) + \tan 5^\circ} \qquad \text{(Equation 14.4-6)}$$

$$Y = L_0 - X(\tan 5^\circ) \qquad \text{(Equation 14.4-7)}$$

Unflared Design

$$Y = \frac{L_O - L_2}{\tan 5^\circ} \qquad \text{(Equation 14.4-8)}$$

$$Y = L_2 \qquad \text{(Equation 14.4-9)}$$

Where:

$X, Y$ = coordinates of beginning of barrier need.

$L_O$ = distance from edge of traveled way to back of obstacle (i.e., the lateral extent of the obstacle).

$L_2$ = distance from edge of traveled way to face of barrier.

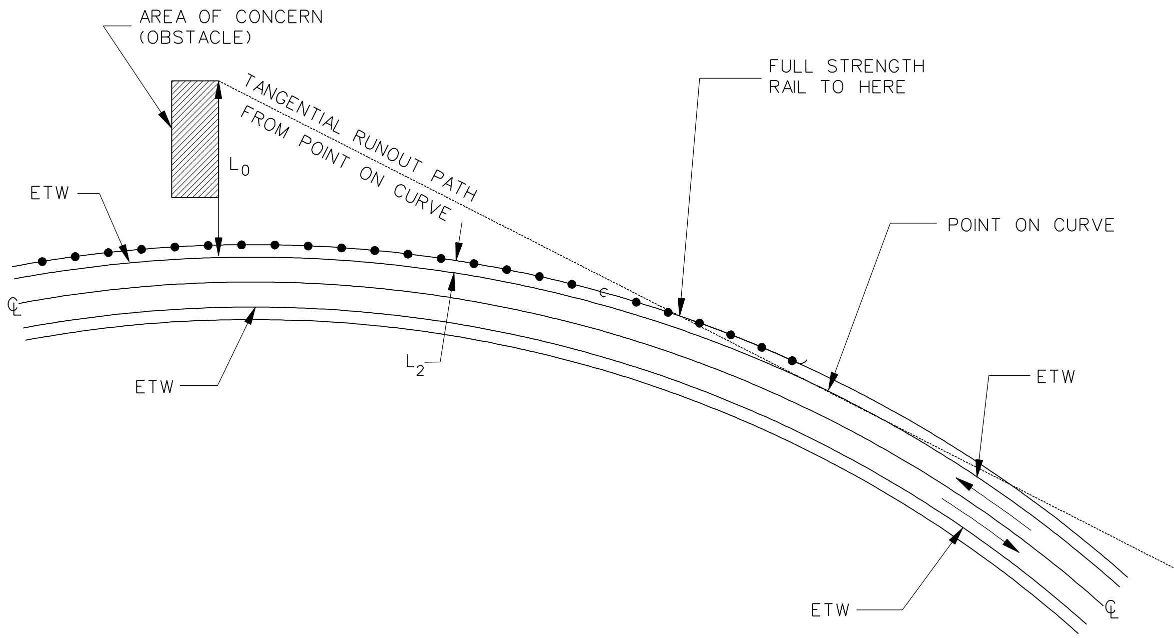
$5^\circ$ = departure angle.

For two-way traffic, use these formulas for the approach treatment for both the adjacent and opposing traffic. For one-way traffic, use these formulas for the approach treatment of the adjacent traffic and extend the guardrail to the far side of the obstacle.

For obstacles located near the clear zone limit, check the necessary barrier length using both the LR formulas (Section 14.4.3.2) and the $5^\circ$ angle formulas (Section 14.4.3.3). Use the method that produces the shorter overall length of guardrail.

### 14.4.3.4 Length of Need (Horizontal Curves)

The length of need formulas (Equations 14.4-2 through 14.4-9) are applicable to tangent highway alignment and where the roadside obstacle is on the inside of a horizontal curve. A vehicle leaving the roadway on the outside of a horizontal curve will generally follow a tangential runout path. Therefore, rather than using the theoretical $L_R$ distance to determine the length of need, use a tangent line from the edge of the traveled way to the outside edge of the obstacle. The length of need is determined by intersecting the barrier installation line with the tangent line. See Figure 14.4F. This intersection can most readily be obtained graphically. If the tangent line is less than $L_R$, use this intersection. However, if the tangent line is greater than $L_R$, use the $L_R$ distance from the back of the obstacle to intersect the installation line to determine the adjacent length. A flared end treatment is generally not used along a horizontal curve.




**BARRIER LENGTH OF NEED**
**(Outside of Horizontal Curve)**

**Figure 14.4F**

### 14.4.3.5 Lateral Placement

Roadside barriers should normally be placed as far as practical from the edge of the traveled way. Such placement gives an errant motorist the best chance of regaining control of the vehicle without impacting the barrier. It also improves sight distance, particularly at nearby intersections. Consider the following factors when determining barrier lateral placement:

1. Deflection: The dynamic deflection distance of the barrier, as measured from the face of the rail, should not be violated. Section 14.4.1 provides the deflection distances for the types of roadside barriers used by the Department.

2. Post Support. At a minimum, provide 600 mm between the back of the barrier post and the slope break in a fill slope to provide adequate soil support for the post.

3. Shy Distance. Drivers tend to "shy" away from continuous longitudinal obstacles along the roadside, such as guardrail. Guardrail should be installed at the edge of the shoulder and should provide a minimum distance of 0.6 m from the face of the rail to the edge of the traveled way. For some roadway widths, this practice will not meet the requirement of the shy line offset as presented in Figure 14.4D. In these cases, installing the guardrail at the shy line offset distance is not practical and is not recommended.

4. Shoulder Widening. Provide a minimum distance of 600 mm between the edge of the traveled way and the face of the rail. If this distance is not available on the existing shoulder, additional widening will be necessary to provide the minimum distance or a design exception will be required.

5. Flare Rate. See Figure 14.4D for the maximum allowable flare rates when using the flare design for advancement guardrail. If the guardrail installation lies both inside and outside of the shy line, provide a flare meeting the requirements for inside the shy line until the installation reaches the shy line offset. At the shy line offset, the flare may then be increased up to the maximum flare for outside the shy line.

### 14.4.3.6 Placement in Conjunction With Curbs

On high-speed facilities (V > 70 km/h), do not place curbs in front of roadside barriers. Where curbs are used in conjunction with roadside barriers on low-speed facilities, the face of the barrier should be in line with the face of the curb (i.e., at the gutter line). Do not use curbs higher than 100 mm with a barrier on new construction facilities. Existing curb installations higher than 100 mm may remain if the installation otherwise meets MDT criteria. Measure the height of the barrier from the pavement surface (e.g., where curbs are on bridges). The designer should note that cable guardrail cannot be used in conjunction with curbing.

#### 14.4.3.7 Placement on Slopes

Slopes in front of a barrier should be 10:1 or flatter. This also applies to the areas in front of the flared section of guardrail and to the area approaching the terminal ends. See the *MDT Detailed Drawings*.

#### 14.4.3.8 Transitions

Barrier transitions are necessary to join two systems with different structural and/or dynamic characteristics. For example, this occurs when guardrail approaches a bridge parapet or CMB installation. The *MDT Detailed Drawings* provide details for the bridge approach section. See the *AASHTO Roadside Design Guide* for additional discussion on barrier transitions.

#### 14.4.3.9 Minimum Length/Gaps

Short runs of barrier have limited value and should be avoided. Generally, a barrier should have at least 30 m of standard guardrail section exclusive of terminal sections and/or transition sections. Short gaps between runs of barrier are undesirable. Therefore, gaps of less than 50 m between barrier termini should be connected into a single run. Exceptions may be necessary for access.

### 14.4.4 Terminal Treatments

Barrier terminal sections present a potential roadside obstacle for run-off-the-road vehicles. However, they are also critical to the proper structural performance of the barrier system. The selection and design of the terminal end section should be carefully coordinated with the barrier system's purpose and length of need. The designer should review the *MDT Detailed Drawings* or manufacturer's specifications to determine what portion of the terminal section can be applied to the length of need.

New terminal systems are continually emerging to address safety problems, and devices are being improved in response to an increased understanding of safety performance, a changing vehicular fleet, the emergence of new materials and other factors.

Unless otherwise noted, see the *MDT Detailed Drawings* for details on the design and placement of the following terminal treatments that are used by the Department:

1. Optional Terminal Sections. Use the optional terminal sections in conjunction with W-beam guardrail on the approach ends for one-way facilities and approach

and departure ends for two-way facilities. The ET-2000 and BEST terminal sections are the only approved optional terminal sections at this time.

2. One-Way Departure Terminal Section. This terminal section is typically used on the departure end of W-beam rail on a one-way facility. It provides structural capacity required at the terminus of the guardrail.

3. Impact Attenuators. The QuadGuard and TRACC impact attenuators are the only approved options at this time. Use these terminal sections for all concrete barriers requiring a terminal end section. See the manufacturer's specifications for design and installation details.

4. Bridge Approach Section. The *MDT Detailed Drawings* provide details for several transition systems used to connect W-beam guardrail to the rigid bridge rail. Attachments to existing structures may require a special design.

5. Intersecting Roadway Terminal Section. This terminal section is used where an approach intersects a run of guardrail or at approaches where there is insufficient room to install one of the optional terminal sections (e.g., approaches next to bridge ends). The terminal is curved around and terminated on the minor approach.

6. Cable Guardrail Terminals. This terminal type is only used with cable guardrail. Cable guardrail terminal sections are generally not considered to be an obstacle.

7. Wy-Bet Box Beam Terminal Section. This terminal section is only used with the box-beam guardrail on the approach ends for one-way facilities and approach and departure ends for two-way facilities.

8. Box-Beam Terminal Section Type 2. Use this terminal section on the departure ends of box-beam rail on one-way facilities. It provides the structural capacity required at the end of the guardrail.

### 14.4.5 Roadside Hardware Supports (Mailbox Supports)

Where roadside hardware (e.g., sign supports, luminaires, traffic signals, mailboxes) cannot be reasonably located outside of the clear zone, they should be made breakaway or shielded with a roadside barrier or impact attenuator. This Section discusses the criteria specifically for mailbox supports. For sign supports, luminaires, etc., see Chapter Six of the *Traffic Engineering Manual*.

Mailboxes and newspaper tubes served by carriers in vehicles may constitute a roadside obstacle, depending upon the placement of the mailbox. The designer should make every reasonable effort to replace all non-conforming mailboxes with the designs that meet the criteria in *A Guide to Mailbox Safety in Montana*, the *AASHTO A Guide for Erecting Mailboxes on Highways*, the *MDT Detailed Drawings* and Chapter Eighteen.

In general, mailboxes should meet the following criteria:

1. Heights. Mailbox heights are usually located so that the bottom of the box is 1.0 m to 1.2 m above the mail stop surface.

2. Post. The maximum strength supports that should be used are nominal 100 mm x 100 mm wood posts or 100 mm diameter wood posts or 50 mm diameter standard galvanized steel pipe post, embedded no more than 600 mm into the ground. The use of concrete anchors is not acceptable.

3. Multiple Mailboxes. To reduce the possibility of ramping, multiple mailboxes should be separated by a distance at least equal to three-fourths of their height above ground.

4. Neighborhood Delivery and Collection Box Units (NDCBU). NDCBU is a cluster of 8 to 16 locked boxes mounted on a pedestal or within a framework. Because the total mass for the NDCBU may range between 45 kg and 90 kg, they are considered a roadside obstacle. NDCBUs are intended to be located in trailer parks, apartment complexes and new residential subdivisions. If there is no alternative, locate NDCBUs on low-speed facilities in conjunction with mailbox turnouts and outside of the clear zone.

# 14.5 MEDIAN BARRIERS

## 14.5.1 Warrants

The following summarizes the Department's criteria:

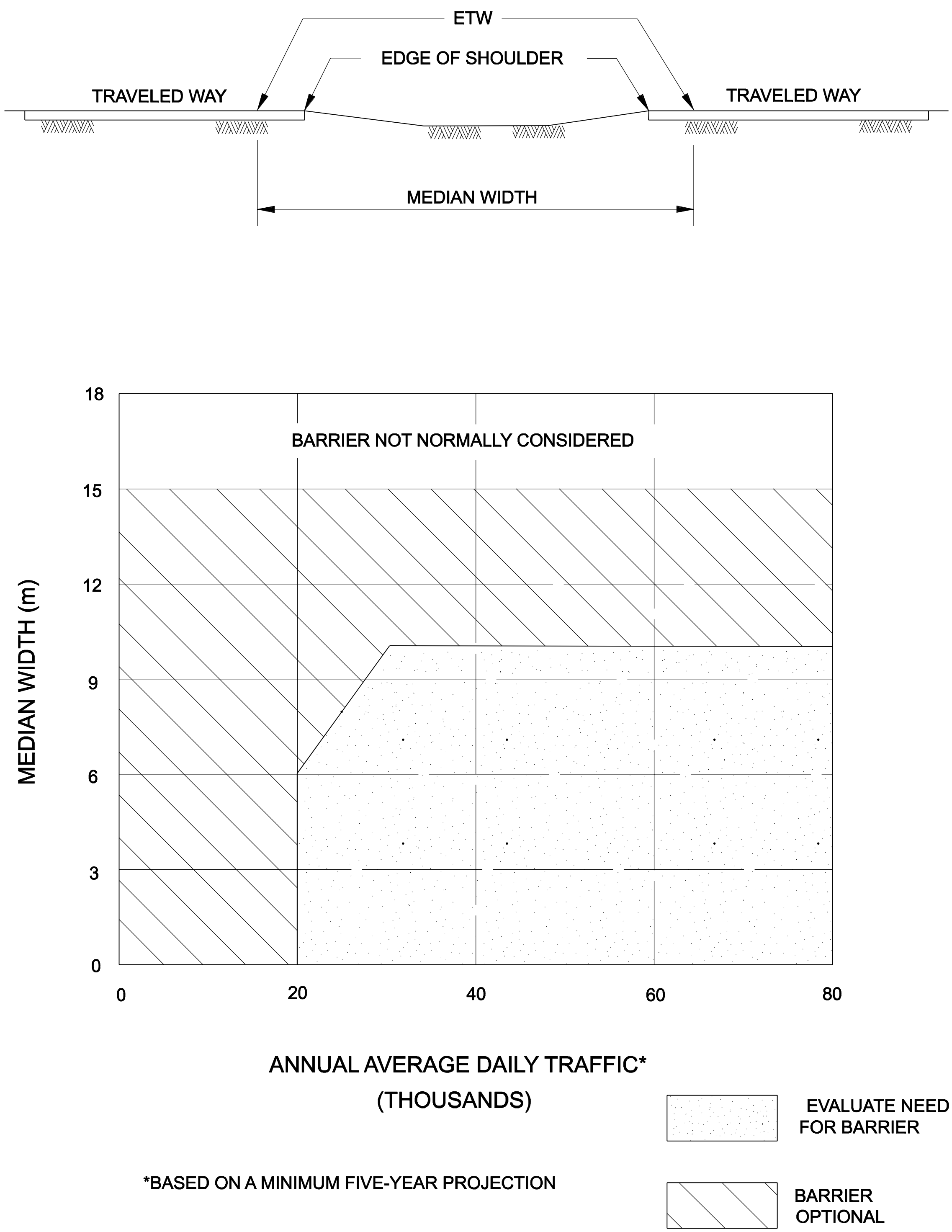
1. Freeways. Figure 14.5A presents the warrants for a median barrier based on median width and traffic volumes. The traffic volumes are based on a minimum 5-year projection. In the areas shown as optional, the decision to use a median barrier will be based on construction and maintenance costs and crossover crash experience. A median barrier may be warranted on medians not within the optional or warranted area, if a significant number of crossover crashes have occurred.

2. Non-Freeways. On other highways, judgment must be used to determine median barrier warrants. On highways without full access control, the median barrier must be terminated at intersections where it has been determined that an opening will be provided. In addition, lower speeds will reduce the likelihood of crossover crashes. Therefore, on non-freeway highways, the designer should evaluate the crash history, traffic volumes and speeds, median width, alignment, sight distance and construction costs to determine the need for a median barrier. Figure 14.5A can be used for guidance.

## 14.5.2 Types

When a median barrier is warranted, due to narrow medians, the Department's policy is to only use a concrete median barrier (CMB). The CMB is a rigid system which will rarely deflect upon impact. A half-section CMB may be necessary where the median barrier must divide to go around a fixed object in the median (e.g., bridge piers). In this situation, the obstacle is typically encased within concrete to create a level surface from CMB face to CMB face.

The "W" beam guardrail is typically used within the median to protect the driver from isolated obstacles (e.g., bridge approaches, piers). The designer should review Section 14.4.3 and the MDT Detailed Drawings for the design and placement criteria of "W" Beam guardrail within the median; i.e., the median is evaluated as a "roadside" in these cases.




**MEDIAN BARRIER WARRANTS**

**Figure 14.5A**

### 14.5.3 Median Barrier Layout

Much of the information presented in Section 14.4.3 on roadside barrier layout also applies to concrete median barriers (e.g., length of need, flare rates). The following presents criteria specifically for the layout of concrete median barriers:

1. Flared/Divided Median Barriers. It may be necessary to intermittently divide a median barrier or to flare the barrier from one side to the other. A fixed object in the median may require this. The median barrier may be divided by one of these methods:

    a. A fixed object may be encased by a CMB.

    b. A half-section CMB may be used on both sides to shield a fixed object.

2. Barrier-Mounted Obstacles. If trucks or buses impact the CMB, their high center of gravity may result in a vehicular roll angle which possibly will allow the truck or bus to impact obstacles on top of the CMB (e.g., luminaire supports). If practical, move these devices to the outside, or provide additional distance between the barrier and obstacle (e.g., bridge piers).

3. Terminal Treatments. As with roadside barrier terminals, CMB terminals also present a potential roadside obstacle for run-off-the-road vehicles. Give careful consideration to the selection and placement of the terminal end. For the terminal ends of concrete median barriers, QUADGUARD Family impact attenuators are presently used. See Section 14.6 for more information on impact attenuators.

# 14.6 IMPACT ATTENUATORS (CRASH CUSHIONS)

## 14.6.1 General

Impact attenuators (crash cushions) are protective systems that prevent errant vehicles from impacting obstacles by either decelerating the vehicle to a stop after a frontal impact or by redirecting it away from the obstacle after a side impact. Impact attenuators are adaptable to many roadside obstacle locations where longitudinal barriers cannot practically be used.

## 14.6.2 Warrants

Impact attenuator warrants are the same as barrier warrants. Once an obstacle is identified, the designer should first attempt to remove, relocate or make the obstacle break away. If the foregoing is impractical, then consider an impact attenuator.

Impact attenuators are most often installed to shield fixed-point obstacles which are close to the traveled way. Examples include exit gore areas (particularly on structures), bridge piers, non-breakaway sign supports and median barrier ends. Impact attenuators are often preferable to guardrail to shield these obstacles. Site conditions and costs will determine whether to use a barrier or impact attenuator.

## 14.6.3 Impact Attenuator Types

Presently, the only two impact attenuators used by Department are the QuadGuard Family and the TRACC. The QuadGuard consists of crushable cartridges surrounded by steel panels set on a monorail system. It is designed for narrow obstacles 600 mm to 2.3 m wide. The backup can be either concrete or tension strut. The QuadGuard system features a “staged” cartridge design that safely decelerates the vehicle. A vehicles’s kinetic energy is gradually dissipated as a vehicle travels from the front to the rear of the system during head-on impacts. The number of bays can be varied to accommodate any design speed. The TRACC is also a staged cartridge design that functions in much the same way as the QuadGuard. The number of bays cannot be adjusted for various speeds. The designer should note that all impact attenuator types are patented and that they should contact the manufacturer for additional information on impact attenuator installations.

## 14.6.4 Impact Attenuator Design

Once an impact attenuator has been selected, the designer must ensure that its design is compatible with the traffic and physical conditions at the site. The following sections will provide criteria for the basic input parameters into impact attenuator design. The designer should contact the manufacturer of the system for the detailed design of the impact attenuator.

### 14.6.4.1 Performance Criteria

For all safety appurtenances, acceptable vehicular deceleration is determined by the occupant impact velocity as measured from full-scale crash tests. Currently, the acceptable limits of performance are based on *NCHRP 350 Recommended Procedures for the Safety Performance Evaluation of Highway Features*. The manufacturer is responsible for designing the impact attenuator to meet the current national performance criteria.

### 14.6.4.2 Design Procedures

Use Figure 14.6A, which shows the number of bays and lengths required for each design speed to determine the appropriate number of bays and required length of the QuadGuard impact attenuator.

The TRACC uses a single size for all design speeds. It is 6.4 m long and 0.785 m from outside face to outside face.

### 14.6.4.3 Side Impacts

The impact attenuator design should allow for safe side impacts. Deflection and pocketing potential should always be reviewed. The QuadGuard Family and the TRACC are designed to redirect impacting vehicles on the side.

| NCHRP 350 Test Level | Design Velocity (km/h) | Number of Bays | Effective Length (m) | Number of Cartridges | |
|---|---|---|---|---|---|
| | | | | Type 1 Front of System | Type 1 Rear of System |
| | 40 | 1 | 1.74 | 2 | 0 |
| TL-1 | 50 | 2 | 2.66 | 2 | 1 |
| | 60 | 2 | 2.66 | 2 | 1 |
| TL-2 | 70 | 3 | 3.57 | 2 | 2 |
| | 80 | 4 | 4.49 | 3 | 2 |
| | 90 | 5 | 5.40 | 3 | 3 |
| TL-3 | 100 | 6 | 6.32 | 4 | 3 |
| | 100 | 7 | 7.23 | 4 | 4 |
| | 110 | 8 | 8.15 | 4 | 5 |
| | 115 | 9 | 9.06 | 4 | 6 |
| | 115 | 10 | 9.98 | 5 | 6 |
| | 115 | 11 | 10.89 | 5 | 7 |
| | 120 | 12 | 11.81 | 5 | 8 |

**THE QUADGUARD SYSTEM**

**Figure 14.6A**

### 14.6.4.4 Placement

Several factors should be considered in the placement of an impact attenuator:

1. Level terrain. All impact attenuators have been designed and tested for level conditions. Vehicular impacts on devices placed on a non-level site could result in an impact at the improper height which could produce undesirable vehicular behavior. Therefore, the attenuator should be placed on a level surface or on a cross slope not to exceed 5%.

2. Curbs. No curbs should be present on new projects at proposed impact attenuator installations. On existing highways, all curbs should be removed at proposed installations if feasible, particularly those that are 100 mm or higher.

3. Surface. A paved, bituminous or concrete pad should be provided under the impact attenuator.

4. Orientation. The impact attenuator should be oriented to accommodate the probable impact angle of an encroaching vehicle. This will maximize the likelihood of a head-on impact. The proper orientation angle will depend upon the design speed, roadway alignment and lateral offset distance to the attenuator. An angle of 5º to 10º, as measured between the highway and impact attenuator longitudinal centerlines, may be appropriate. See the manufacturer's data for more information.

5. Reserve Area. The designer should, as early as practical in the project design process, determine the need for and approximate dimensions of impact attenuators. This will avoid late changes which could significantly affect the project design.